

Northwest Territories Air Quality Report **2009**



Northwest Territories Environment and Natural Resources

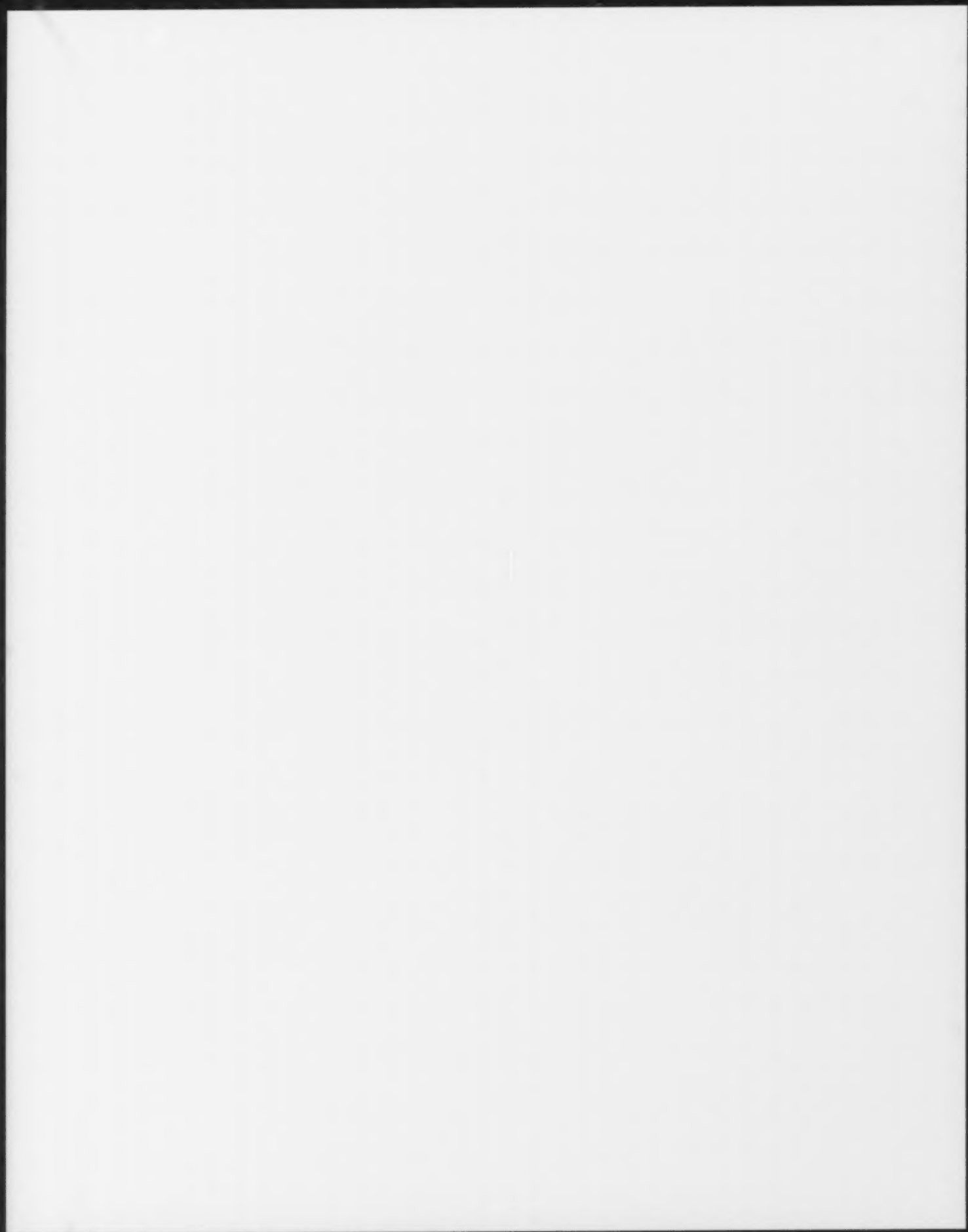


TABLE OF CONTENTS

Introduction	3
Operations (Network).....	4
Developments in 2009.....	8
Future Plans	9
NWT Air Quality Standards	10
Yellowknife Air Quality	11
Particulate Matter	11
Fine Particulate (PM _{2.5}) and Coarse Particulate (PM ₁₀)	12
Particulate Speciation.....	14
Sulphur Dioxide (SO ₂).....	16
Ground Level Ozone (O ₃)	17
Nitrogen Oxides (NO _x)	19
Carbon Monoxide (CO).....	21
Inuvik Air Quality	22
Hydrogen Sulphide (H ₂ S)	22
Sulphur Dioxide (SO ₂).....	22
Nitrogen Oxides (NO _x)	22
Fine Particulate (PM _{2.5})	23
Coarse Particulate (PM ₁₀)	24
Ground Level Ozone (O ₃)	25
Fort Liard Air Quality	26
Hydrogen Sulphide (H ₂ S)	26
Sulphur Dioxide (SO ₂).....	26
Fine Particulate (PM _{2.5})	27
Coarse Particulate (PM ₁₀)	28
Nitrogen Oxides (NO _x)	28
Ground Level Ozone (O ₃)	29
Norman Wells Air Quality	30
Hydrogen Sulphide (H ₂ S)	30
Sulphur Dioxide (SO ₂).....	30
Nitrogen Oxides (NO _x)	31
Fine Particulate (PM _{2.5})	32
Ground Level Ozone (O ₃)	33

Snare Rapids.....	34
Daring Lake Seasonal Particulate.....	35
Appendix A: Monitoring History	36
Appendix B: Air Pollutants	38
Total Suspended Particulate (TSP).....	38
Arsenic.....	38
Particulate Matter (PM _{2.5}) and (PM ₁₀)	39
Sulphur Dioxide (SO ₂).....	40
Hydrogen Sulphide (H ₂ S).....	40
Nitrogen Oxides (NO _x).....	40
Ground Level Ozone (O ₃)	41
Carbon Monoxide (CO).....	41
Acid Deposition.....	42

INTRODUCTION

The Environment Division (ED) of the Department of Environment and Natural Resources (ENR) monitors air quality in the Northwest Territories (NWT). ENR maintains and operates the NWT Ambient Air Quality Monitoring Network, consisting of four monitoring stations located in Yellowknife, Inuvik, Fort Liard and Norman Wells. Each station is capable of continuously sampling and analyzing a variety of air pollutants and meteorological conditions. The Yellowknife and Inuvik stations are operated in partnership with the National Air Pollution Surveillance (NAPS) program – a joint federal/provincial/territorial monitoring network, with the objective of tracking urban air quality trends throughout Canada. A secondary overall objective of the stations is to establish baseline levels of SO₂, H₂S, NO_x, O₃ and PM ahead of development as well as track the trends and cumulative impacts from source emissions should they occur.

ENR also monitors acid precipitation at Snare Rapids, in cooperation with the Canadian Air and Precipitation Monitoring Network (CAPMoN).

The 2009 Annual Air Quality Report summarizes the air quality information collected in 2009, along with some discussion of trends. *Statistical assessment of the results can be made available upon request.* The report also provides information on network operations, the air pollutants monitored and the air quality standards used in assessing the monitoring results. Further information, including 'almost real-time' air pollutant readings, can be found by visiting the NWT Air Quality Monitoring Network web site at <http://www.air.enr.gov.nt.ca/NWTAQ/NetworkSummary.aspx>

After reading this report, if you have questions or require further information, you can contact:

Environment Division
Department of Environment and Natural Resources
Government of the Northwest Territories
P.O. Box 1320
Yellowknife, NT X1A 2L9

Telephone: (867) 873-7654

Facsimile: (867) 873-0221

This report is also available on the Internet at
http://www.enr.gov.nt.ca/_live/pages/wpPages/publications.aspx

OPERATIONS (NETWORK)

The NWT Air Quality Monitoring Network consists of four permanent monitoring stations located in Yellowknife, Inuvik, Fort Liard and Norman Wells. The stations are climate-controlled trailers and include state-of-the-art monitoring equipment capable of continuously sampling and analyzing a variety of air pollutants and meteorological conditions. Pollutants monitored vary by station, but include sulphur dioxide (SO_2), hydrogen sulphide (H_2S), fine particulate ($\text{PM}_{2.5}$), coarse particulate (PM_{10}), ground level ozone (O_3), carbon monoxide (CO), nitrogen oxides (NO_x) and particle speciation for 32 constituents. Wind speed, wind direction and temperature are also monitored. For additional information on air pollutants, see Appendix B.

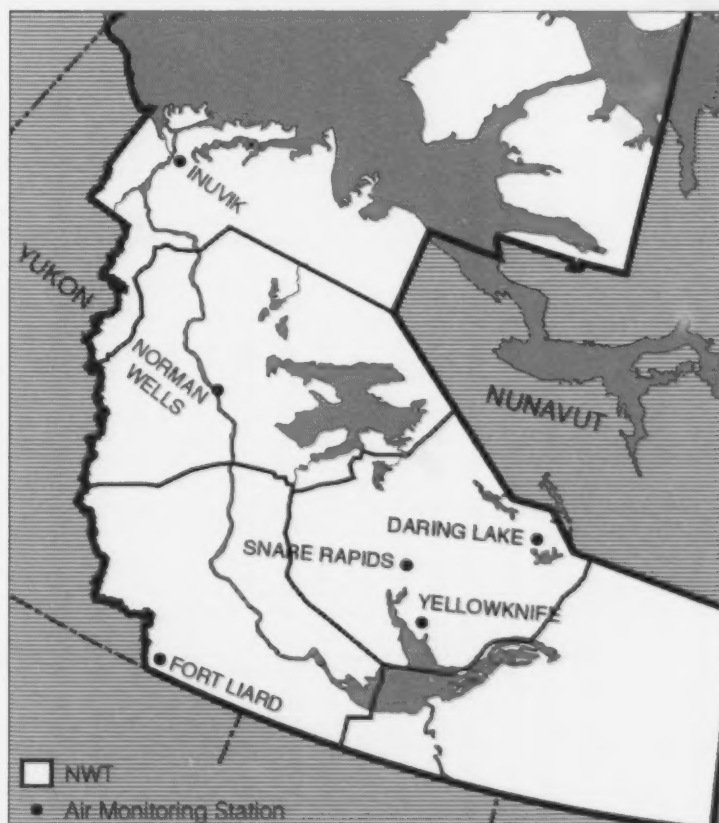


Table 1 shows the breakdown of the NWT Air Monitoring Network by substances and meteorological parameters monitored at each station.

Table 1

Substances Monitored by Station											
Stations	Particulate Matter			Gaseous					Precipitation	Meteorological Monitoring	
	Particle Speciation	PM _{2.5} – Fine Particulate	PM ₁₀ – Coarse Particulate	SO ₂ Sulphur Dioxide	H ₂ S Hydrogen Sulphide	NO _x Nitrogen Oxides	O ₃ Ground Level Ozone	CO Carbon Monoxide	Acidic Deposition	Wind Speed and Direction	Air Temperature
Yellowknife	✓	✓	✓	✓		✓	✓	✓		✓	✓
Inuvik		✓	✓	✓	✓	✓	✓			✓	✓
Norman Wells		✓		✓	✓	✓	✓			✓	✓
Fort Liard		✓	✓	✓	✓	✓	✓			✓	✓
Snare Rapids									✓		

Using a sophisticated data acquisition system (DAS) and communications software, data from each station is automatically transmitted every hour to ENR headquarters in Yellowknife, allowing almost real-time review of community air quality by ENR staff. The data also undergoes a series of 'on the fly' validity checks before being archived by ENR's data management, analysis and reporting system.

The Yellowknife and Inuvik stations are part of a larger national network that monitors the common or criteria air pollutants in urban centres across Canada. The National Air

Pollution Surveillance (NAPS) Network is a joint federal/provincial/territorial program, incorporating approximately 290 stations located in 175 communities, that monitor the same particulate and gaseous substances as those sampled in Yellowknife and Inuvik. Data from both these NWT stations, along with data from other cities, is summarized and assessed, with results published in the NAPS annual data reports available at http://www.etc-cte.ec.gc.ca/publications/napsreports_e.html.

The NAPS Network has a stringent quality assurance/quality control (QA/QC) program that ensures Canada-wide data is comparable. Participation in the NAPS program requires ENR to follow these QA/QC procedures at the Yellowknife and Inuvik sites, and ENR, in turn, applies these procedures at the other stations.








The Fort Liard and Norman Wells stations are territorial stations that were set up in response to increasing resource development activity in the NWT and the potential for the associated emissions to affect air quality. The NAPS Inuvik station still fulfills its original territorial goals, along with its national urban monitoring objective. The primary territorial objective of these stations is to establish baseline levels of SO_2 , H_2S , NO_x , O_3 and PM ahead of development as well as track the trends and cumulative impacts from source emissions should they occur.

ENR is involved in a second federal monitoring system; the Canadian Air and Precipitation Monitoring Network (CAPMoN). CAPMoN is a non-urban monitoring network with 33 measurement sites in Canada and one in the United States that is designed to study the regional patterns and trends of atmospheric pollutants such as acid rain, smog, particulate matter and mercury, in both air and precipitation. Unlike NAPS, CAPMoN locates sites to limit the effect of anthropogenic sources. Most sites are remote and data is considered representative of background values. ENR, with assistance from NWT Power Corporation staff, operates NWT's sole CAPMoN station at the Snare Rapids hydro-electric site, consisting of an acid precipitation collector and ozone analyzer. Daily rain and snow samples are collected and forwarded to the CAPMoN laboratory for analysis, and the data is used by both Environment Canada and ENR.

ENR has historically collected fine particulate data at the Daring Lake Tundra Ecosystem Research Station during the summers to establish typical background concentrations in the NWT. This research station is part of a circumpolar initiative called the Polar Continental Shelf Project and is designed as a research facility to conduct long-term research and monitoring of the tundra ecosystem. Instrumentation malfunctions in 2009 resulted in the temporary discontinuation of the air quality monitoring at Daring Lake; however, it is anticipated that monitoring will resume in the future.

Table 2 presents the various government affiliations involved with the air quality monitoring stations in the NWT.

Table 2

NWT Air Quality Network			
 Environment and Natural Resources – Environment Division	Partnership/ Contract	Stations	Network
		Yellowknife and Inuvik	 Environment Canada  Environnement Canada National Air Pollution Surveillance
		Fort Liard and Norman Wells	 Northwest Territories stations
	NWT Power Corporation	Snare Rapids	 Environment Canada  Environnement Canada Canadian Air and Precipitation Monitoring
	NWT Tundra Ecological Research Station	Daring Lake	 Northwest Territories stations

Air quality monitoring in the NWT has evolved over time, beginning with a single TSP monitor in Yellowknife back in 1974, and progressing through various monitoring locations and equipment to reach the current stage of development.

Appendix A traces the history of air quality monitoring in the NWT, while previous ENR Annual Air Quality Reports can be found at: http://www.enr.gov.nt.ca/_live/pages/wpPages/publications.aspx

DEVELOPMENTS IN 2009

A continuous PM_{10} monitor was installed in the Norman Wells station in 2009, which completed the particulate monitoring installations throughout the network.

The Yellowknife station has historically conducted particulate sampling using a high volume air sampler; however, this program was terminated at the end of 2008 as the instrument is no longer supported by NAPS (Environment Canada). The operation of the other non-continuous particle sampler, the automated partisol dichotomous sampler (dichot), continued through 2009. The trends of the PM_{10} readings provided by this instrument correlate with those of the TSP readings from the former high-vol and, as such, can be used to track trends of annual dust levels in its place.

The Daring Lake particulate sampler experienced mechanical issues and, as it also is no longer supported or manufactured, the sampling program was temporarily discontinued in 2009. ENR anticipates that monitoring will resume in the future.

FUTURE PLANS

ENR will be upgrading the existing air quality data management, analysis and reporting system in 2010 to a newer version. This will include:

- Replacing the existing traditional data loggers with PC-based industrial loggers
- Updating to the data transfer mechanisms to provide the ability for ENR staff to conduct remote diagnostic evaluation of the instruments, expediting the troubleshooting and repair process.
- Modifying the web site to the latest architecture, which will harmonize with NAPS format/layout.

The Inuvik station is currently located in an area of town that is experiencing construction activities. To ensure that the readings are representative of the general air quality in Inuvik, ENR will be relocating the station in 2010 to a site that will continue to meet the NAPS siting requirements into the future.

The automated partisol dichotomous sampler (non-continuous particle sampler) operated at the Yellowknife station will be replaced in 2010 with a manual version of the same instrument. Due to the reduced number of moving parts, this unit will be capable of operating under the extreme winter conditions experienced in Yellowknife, and will therefore be able to be administered outside, as specified in the NAPS' standard operating procedures.

NWT AIR QUALITY STANDARDS

The Government of the NWT has adopted a number of concentration limits for protection of ambient (outdoor) air quality in the NWT. These limits apply to select pollutants and are contained in the "Guideline for Ambient Air Quality Standards in the Northwest Territories", established under the NWT *Environmental Protection Act*. They are summarized in Table 3 below.

The NWT standards are used in the assessment of air quality monitoring data as well as determining the acceptability of emissions from proposed and existing developments. Where NWT standards are not available for a particular pollutant, the Canadian National Ambient Air Quality Objectives (national standards) or limits established in other jurisdictions are used.

Table 3

NWT Ambient Air Quality Standards		
Parameter and Standard	Concentration ($\mu\text{g}/\text{m}^3$)*	Concentration (ppbv)**
Sulphur Dioxide (SO_2)		
1-hour average	450	172
24-hour average	150	57
Annual arithmetic mean	30	11
Ground Level Ozone (O_3)		
8-hour running average	127	65
Total Suspended Particulate (TSP)		
24-hour average	120	
Annual geometric mean	60	
Fine Particulate Matter ($\text{PM}_{2.5}$)		
24-hour average	30	

* Micrograms per cubic metre

** Parts per billion by volume

The "Guideline for Ambient Air Quality Standards in the Northwest Territories" provides additional information on the application of the NWT standards and the pollutants of concern. For additional information on air pollutants, see Appendix B.

YELLOWKNIFE AIR QUALITY

ENR, in partnership with the Canadian NAPS Program, operates the air quality monitoring station in Yellowknife.

This station is located at the École Sir John Franklin High School (Sir John Franklin) and continuously monitors criteria air contaminants (CAC's) O_3 , SO_2 , NO_x , CO , fine particulate ($PM_{2.5}$) and coarse particulate (PM_{10}). The station also monitors wind speed, wind direction and temperature, which greatly assist in identifying possible sources of unusual or elevated readings.

Additional non-continuous monitoring at the station consists of an automated partisol dichotomous particulate sampler (dichot), which is used for establishing the speciation of particles.

The air quality monitoring results from the consolidated station at Sir John Franklin are discussed in the following sections, and historical data is used to demonstrate trends where applicable.

Particulate Matter

Yellowknife's greatest source of particulate is dust from roads, especially in the spring when the snow cover disappears and exposes winter sand and gravel on city streets to the effects of wind and vehicle disturbance. Forest fires, mining activities and combustion products from vehicles, heating and electricity generation also raise particulate levels. *Please note that forest fire events are observed and documented by regional ENR staff as they occur (i.e. visible smoke and olfactory indications of smoke) and this qualitative data serves as a validation to the conclusions drawn from measured $PM_{2.5}$ readings.*

ENR uses two methods of sampling the particulate size fractions of PM in Yellowknife – Beta Attenuation Mass Monitors (BAM) and a filter-based partisol dichotomous sampler (dichot). The BAM methodology provides continuous, almost real-time (hourly) analysis of particulate concentrations, while the dichot samples on a 24-hour basis every six days. The dichot sampler simultaneously collects both the $2.5\mu m$ and less and the 2.5 to $10\mu m$ particulate size fractions on a filter media. The filters require laboratory analysis to determine particulate



Sir John Franklin Station

concentrations and, unlike the BAM, do not provide timely information for real-time air quality assessment. However, the filters can also be analyzed for a whole suite of additional parameters, including metals. The dichot compliments the BAM in that particle identification can be determined, which provides more in-depth information about fine and coarse particulate.

Fine Particulate ($PM_{2.5}$) and Coarse Particulate (PM_{10})

There are two BAMs operating at the Yellowknife station; one measures $PM_{2.5}$, while the other measures PM_{10} .

There were no $PM_{2.5}$ BAM readings at the Sir John Franklin station in 2009 that exceeded the NWT 24-hour standard ($30 \mu g/m^3$). Impacts to $PM_{2.5}$ levels from forest fires were observed in July and August of 2009; however, their impacts were negligible.

Figure 1: 2009 Yellowknife BAM $PM_{2.5}$

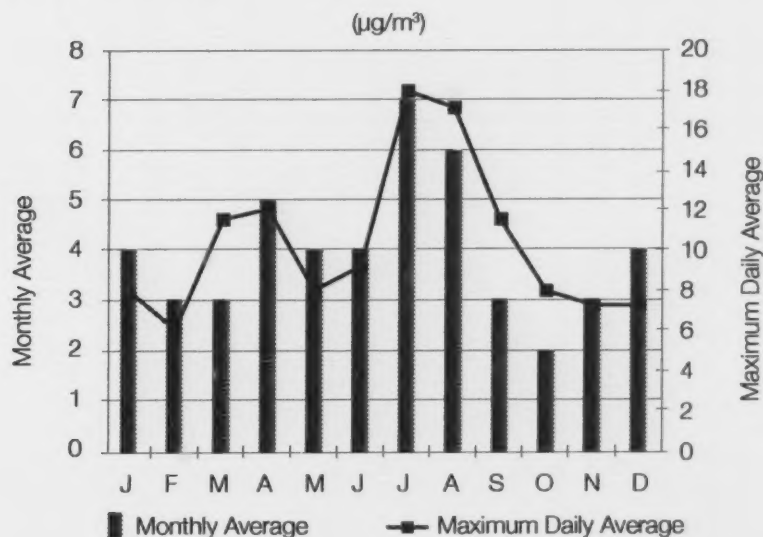


Figure 1 shows the monthly averages and maximum daily average per month measured at the Sir John Franklin station in 2009 on the BAM $PM_{2.5}$. The highest daily average concentration was $18 \mu g/m^3$, measured in July.

Figure 2: 2006 - 2009 Summary Yellowknife BAM PM_{2.5}

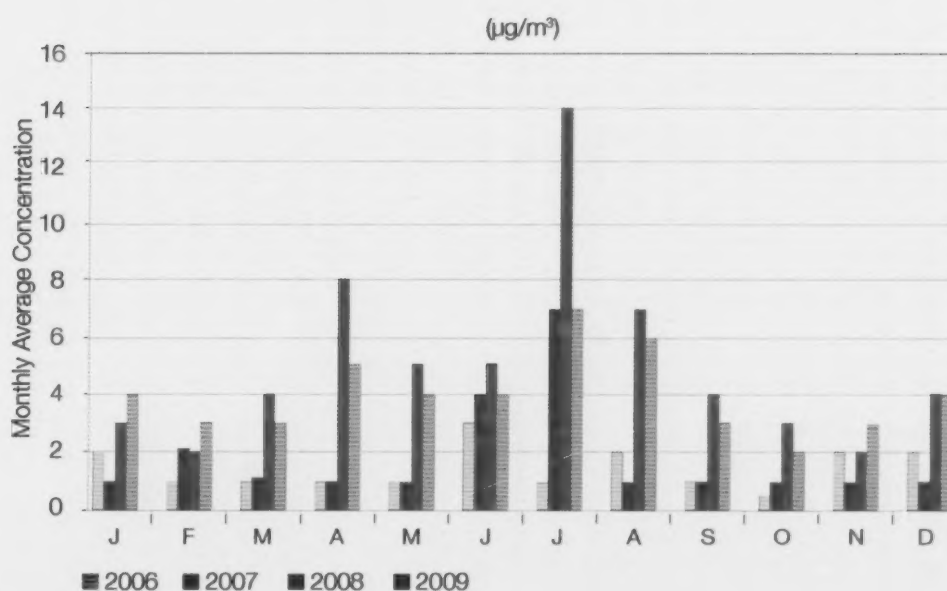


Figure 2 summarizes the monthly average BAM PM_{2.5} data over the last four years. The overall trends indicate that PM_{2.5} levels increase during the summer months, which is typically attributed to forest fires, which occur during this time of year. As the graph indicates, the 2009 fire season did not have a significant effect relative to previous years.

The NWT has not adopted a standard for PM₁₀, but several Canadian jurisdictions (e.g. BC, Ontario, Newfoundland and Labrador) have adopted a 24-hour average for PM₁₀ of 50µg/m³ as an acceptable limit.

Overall, there were four exceedances of the 50µg/m³ limit in 2009 at the Yellowknife station, most of which occurred in April, which can be attributed to residual road gravel following spring thaw. Historically, starting in April, Yellowknife has experienced several episodes of elevated PM₁₀ levels, which sometimes result in complaints from residents, prompting the City to initiate road sweeping ahead of their normal spring clean-up schedule.

Figure 3: 2009 Yellowknife PM₁₀

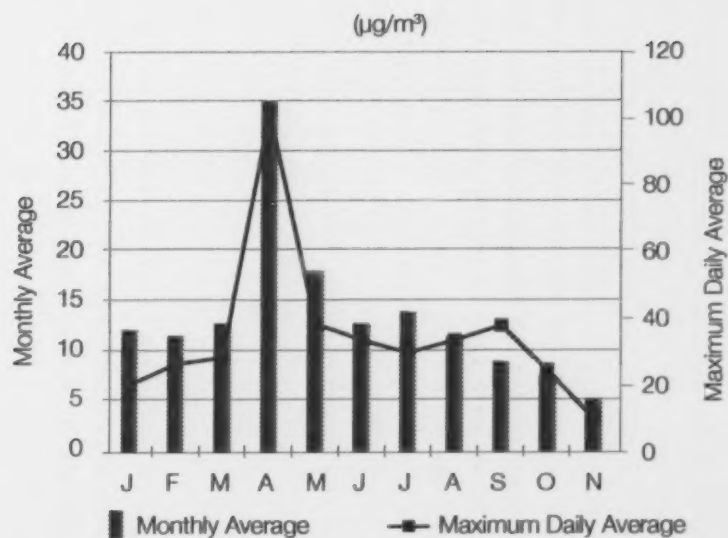


Figure 3 shows the BAM PM₁₀ monthly averages and maximum daily averages per month measured at the station in 2009. The highest maximum daily concentration was 100µg/m³ occurring in April.

Particle Speciation

Every six days, on a predetermined schedule, particulate samples are collected over a 24-hour period (midnight to midnight) using an automated dichotomous partisol sampler (dichot). The sampler draws a measured volume of air through a filter to collect the suspended particulate in multiple fractions, including PM_{2.5} and PM_{2.5 to 10}. The filters are sent to Environment Canada's NAPS laboratory in Ottawa, and are processed for a suite of 32 constituents.

Analytical process at the NAPS laboratory often results in 1-year time lags. As a result, the 2009 speciation results have not yet been received. Trend analysis of this data will be presented in next year's NWT Annual Air Quality Report.

An element of focus in Yellowknife has historically been arsenic, due to the historically elevated levels in town as a result of past local gold mining operations. The most recent

data available on arsenic concentrations in ambient air in Yellowknife was measured from the high volume air sampler up to the end of 2008. This data was not received in time for publication in the 2008 report and, as such, it is presented in this year's report instead. Recall, the high-vol was decommissioned following the 2008 monitoring year due to instrument changes at the NAPS level.

The results of the concentrations of arsenic measured from the hi-vol in 2008 in Yellowknife indicate an annual average concentration of $0.0034\mu\text{g}/\text{m}^3$. The highest arsenic concentration measured over a 24-hour period in 2008 was $0.0518\mu\text{g}/\text{m}^3$, measured in July.

Figure 4: Yellowknife Total Arsenic

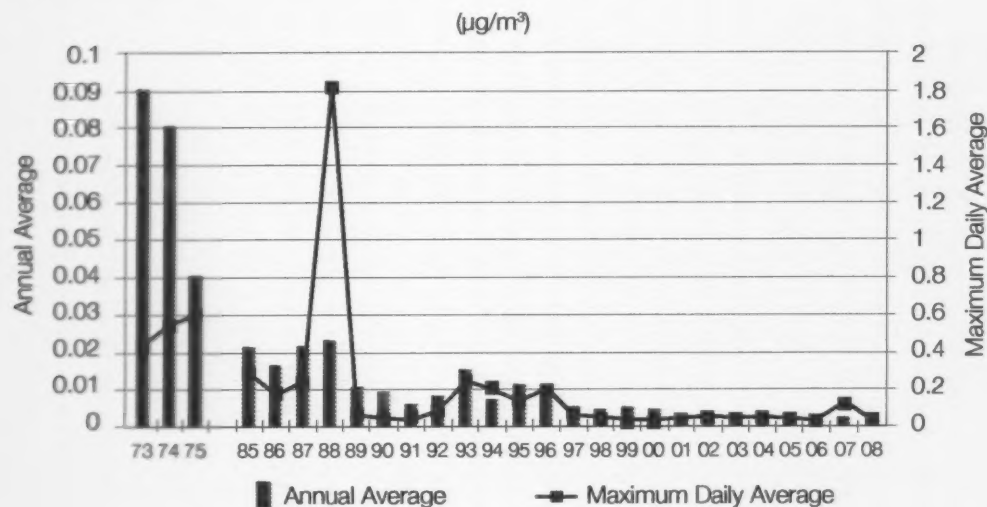


Figure 4 summarizes the historical concentrations of arsenic measured in Yellowknife up to 2008. The bars represent annual averages, while the line shows the highest total arsenic level measured over a 24-hour period for a given year. It is apparent that arsenic concentrations in Yellowknife have fallen from the historical elevated concentrations in the 1970s and 1980s. No exceedances of the Ontario Guideline ($0.3\mu\text{g}/\text{m}^3$) have occurred since 1988 and the average arsenic concentration over the last decade is less than $0.006\mu\text{g}/\text{m}^3$ – below all but the most stringent World Health Organization (WHO) risk estimate concentration (see Appendix B). In recent years, the overall average has decreased further, to less than $0.003\mu\text{g}/\text{m}^3$.

Studies in the United States show an average arsenic concentration in air of <0.001 to $0.003\mu\text{g}/\text{m}^3$ in remote areas, with concentrations of 0.020 to $0.030\mu\text{g}/\text{m}^3$ in urban areas, while Canadian urban areas range from 0.0005 to $0.017\mu\text{g}/\text{m}^3$ (WHO, 2000). Yellowknife arsenic results over the last decade indicate annual concentrations ranging from 0.002 to $0.015\mu\text{g}/\text{m}^3$ – comparable to concentrations measured in other urban areas. Since 1999, the levels have decreased and the annual average concentrations (0.002 to $0.004\mu\text{g}/\text{m}^3$) are similar to those in remote areas.

Based on the previous discussion, it appears that concentrations of airborne arsenic in Yellowknife are typical of those found in remote areas and that health risks due to inhalation are minimal.

Sulphur Dioxide (SO_2)

Continuous monitoring for SO_2 has been conducted in Yellowknife at several locations since 1992.

There were no exceedances of the NWT hourly ($450\mu\text{g}/\text{m}^3$) and 24-hour ($150\mu\text{g}/\text{m}^3$) standards. The annual average was less than $4\mu\text{g}/\text{m}^3$, a level that is well below the NWT ($30\mu\text{g}/\text{m}^3$) standard.

The vast majority of the hourly concentrations recorded in 2009 were only background or slightly greater, with a maximum hourly concentration of $11\mu\text{g}/\text{m}^3$. The concentrations reflect naturally occurring SO_2 , usually in the range of 3 to $4\mu\text{g}/\text{m}^3$, and small amounts from the burning of fossil fuels.

In the past, the largest sources of SO_2 in the Yellowknife area were the gold mine ore roasters, the most recent being Giant Mine. The highest levels of SO_2 in the Yellowknife area were measured downwind from the mine. Since the mine was closed in 1999, only background levels have been recorded.

Figure 5: 1994 - 2009 Summary Yellowknife Sulphur Dioxide

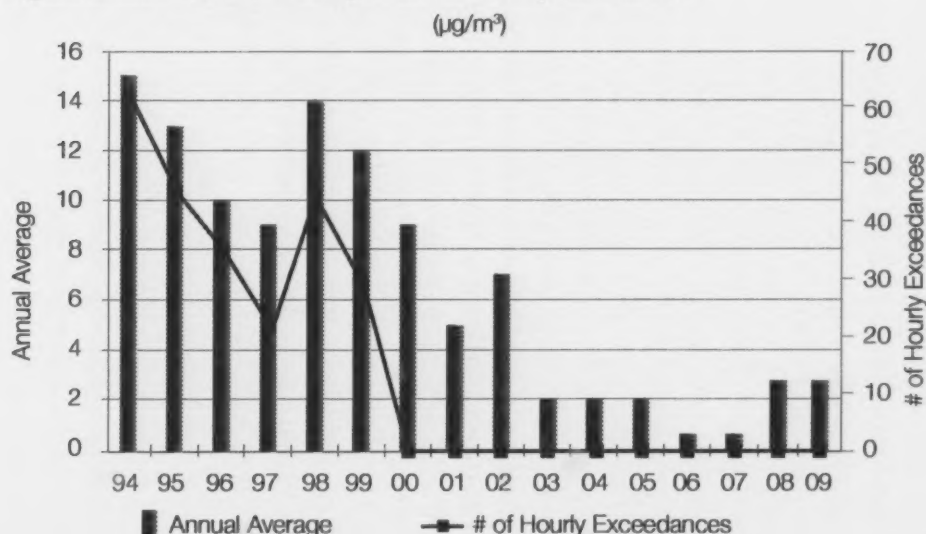


Figure 5 shows the general trends in SO_2 levels measured in Yellowknife air from 1994 to 2009. The bars track the annual average of SO_2 and the line shows the number of times in each year that the NWT 1-hour standard was exceeded. As illustrated by the graph, the number of exceedances has fallen to zero since the closure of Giant Mine in 1999. The 2009 data continued the trend of recent years.

Ground Level Ozone (O_3)

A continuous O_3 analyzer has been operated in Yellowknife since 1998, while the current analyzer has been operating at the Sir John Franklin station since February of 2003.

The maximum 8-hour average in 2009 was $96 \mu\text{g}/\text{m}^3$, which occurred in April and met the 8-hour NWT standard ($127 \mu\text{g}/\text{m}^3$). The maximum 1-hour average was $98 \mu\text{g}/\text{m}^3$, which met the national standard ($160 \mu\text{g}/\text{m}^3$). The 2009 annual hourly average was $46 \mu\text{g}/\text{m}^3$.

Detectable concentrations of O_3 exist even in remote areas due to naturally occurring sources of the precursor gases such as forest fires and volatile organic compounds (VOC) emissions from trees and the introduction of stratospheric ozone to lower elevations resulting from atmospheric mixing processes. These background concentrations typically are in the range of 40 to $80 \mu\text{g}/\text{m}^3$. In large urban areas (and areas downwind), ozone

concentrations can be much higher than typical background due to the additional emissions of precursor gases (see Appendix B).

Figure 6: 2008 Yellowknife Ozone

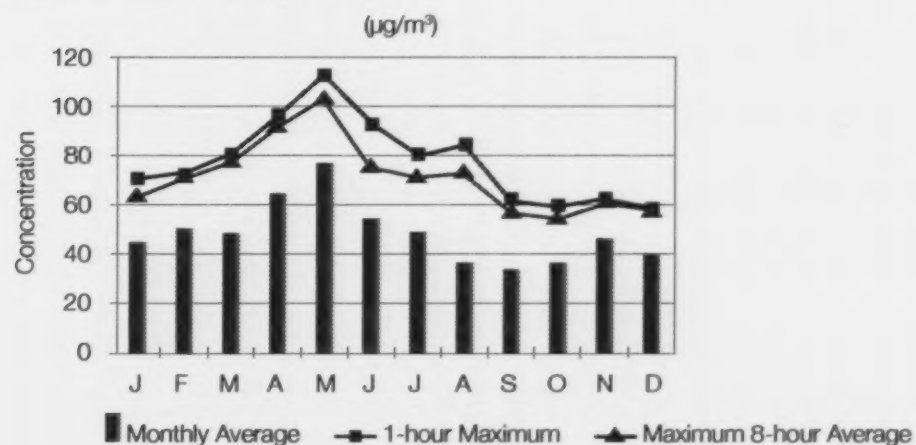
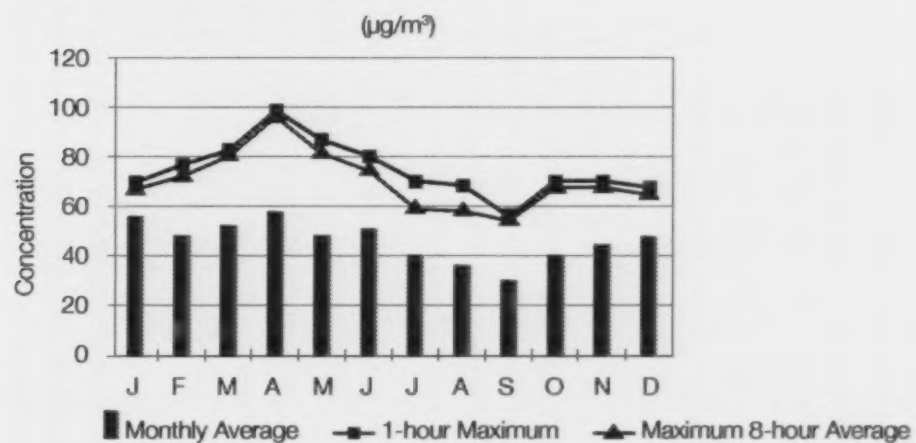


Figure 7: 2009 Yellowknife Ozone



Figures 6 and 7 show the maximum hourly reading and maximum 8-hour average per month as well as the monthly averages recorded for 2008 and 2009.

The Figures illustrate the typical spring maximum, which commonly occurs at remote monitoring stations located in mid to high latitudes in the northern hemisphere and the source of which is the subject of considerable scientific debate. Typical monthly ozone concentrations at remote sites in Canada range between 40 and 80 $\mu\text{g}/\text{m}^3$, and Yellowknife concentrations for both years fell below or within this range, indicating that most of the O_3 detected is likely naturally occurring or background.

Nitrogen Oxides (NO_x)

The NO_x gas analyzer provides continuous information on NO , NO_2 and NO_x . However, the focus is on NO_2 due to the greater health concerns associated with this pollutant and the availability of national air quality standards for comparison (see Appendix B).

The 2009 results indicated that there were no exceedances of the 1-hour, 24-hour or annual national standards for NO_2 , (400, 200, 60 $\mu\text{g}/\text{m}^3$, respectively). The maximum 1-hour average was 44 $\mu\text{g}/\text{m}^3$, the maximum 24-hour average was 27 $\mu\text{g}/\text{m}^3$, while the annual average was 4 $\mu\text{g}/\text{m}^3$.

Figure 8: 2008 Yellowknife Nitrogen Dioxide

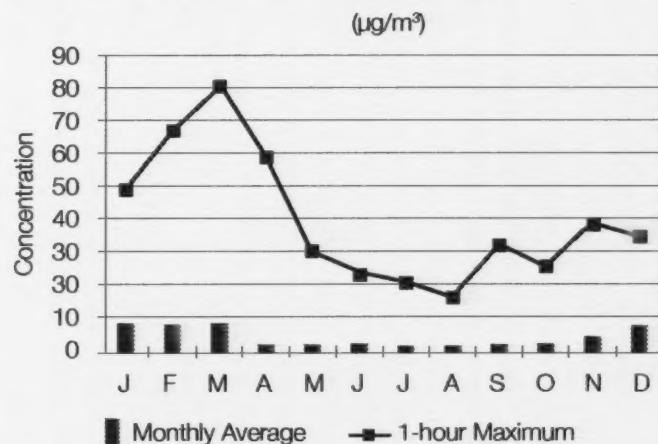
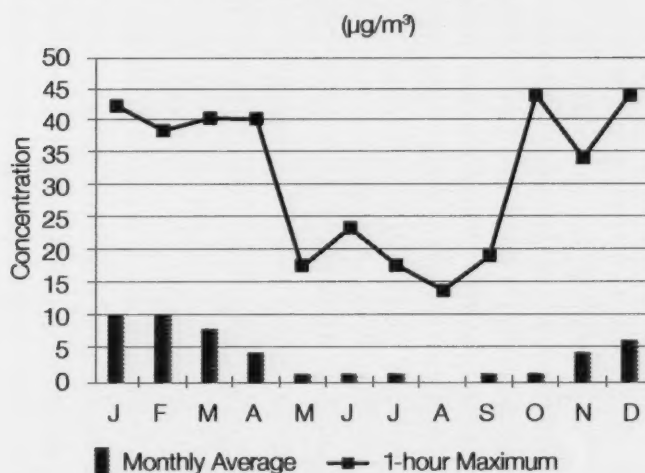


Figure 9: 2009 Yellowknife Nitrogen Dioxide



Figures 8 and 9 show the 2008 and 2009 monthly averages and highest hourly concentrations. Both the highest monthly averages and the highest hourly concentrations occurred during the winter months. This is likely caused by increased emissions from fuel combustion for residential and commercial heating, and idling vehicles, as well as short-term "rush hour" traffic influences. The effects of these emissions on winter-time air quality can be increased when combined with stagnant meteorological conditions. Cold, calm days can result in an atmospheric situation where the normal decrease in air temperature with elevation is reversed and a zone of colder air is present at ground level. This zone of colder air and the lack of wind act to restrict dispersion and trap pollutants close to the ground.

Carbon Monoxide (CO)

The 2009 data continued the extremely low CO readings measured in 2008 and were well below the national standards (see Appendix B). In 2009, the maximum 1-hour average was 2.2 mg/m³ and the annual average was 0.4 mg/m³. Given the absence of heavy traffic volumes in Yellowknife, low levels of CO are expected.

Figure 10: 2009 Yellowknife Carbon Monoxide

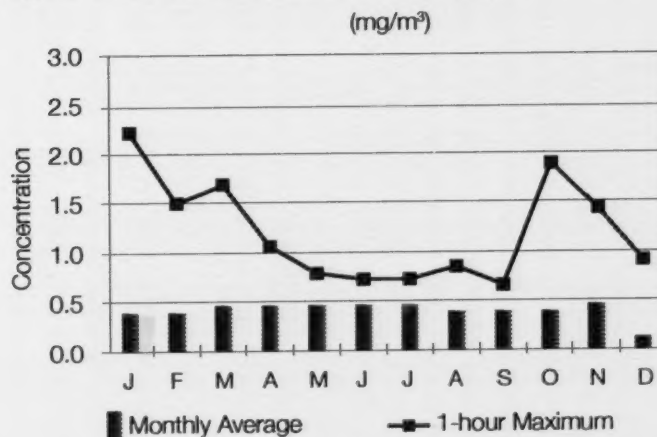


Figure 10 shows the 2009 monthly averages and highest hourly concentrations for CO in Yellowknife.

INUVIK AIR QUALITY

The focus of the monitoring station in Inuvik is to gather baseline community air quality information and to track trends and cumulative effects of pollutant sources over time. In January 2006, the station was incorporated into the National Air Pollution Surveillance (NAPS) Network to provide air quality information to this national monitoring network for comparison to other communities in Canada.

The station measures SO_2 , H_2S , NO_x , O_3 , $\text{PM}_{2.5}$ and PM_{10} . This station has been in operation since 2003.

Hydrogen Sulphide (H_2S)

The data collected in 2009 continues to indicate very low H_2S concentrations in Inuvik – essentially non-detectable. Most of the readings are less than $1\mu\text{g}/\text{m}^3$, which is below the detectable limits of the instrumentation and within the 'noise' range.

The maximum recorded 1-hour average was $3\mu\text{g}/\text{m}^3$, while the maximum 24-hour average was $3\mu\text{g}/\text{m}^3$. There were no exceedances of the Alberta Guidelines (1-hour average of $14\mu\text{g}/\text{m}^3$ and a 24-hour average of $4\mu\text{g}/\text{m}^3$). These results are consistent with the readings collected in previous years.

Sulphur Dioxide (SO_2)

The annual average was less than $1\mu\text{g}/\text{m}^3$, the maximum 1-hour average was $8\mu\text{g}/\text{m}^3$. The SO_2 concentrations measured in 2009 were very low and similar to previous year's results, with no exceedances of the NWT hourly ($450\mu\text{g}/\text{m}^3$), 24-hour ($150\mu\text{g}/\text{m}^3$) and annual average ($30\mu\text{g}/\text{m}^3$) standards.

Nitrogen Oxides (NO_x)

The Inuvik NO_x analyzer suffered a serious breakdown in October of 2008 and was not fully operational again until November of 2009. This resulted in the inability to collect NO_2 data for 2009.

Fine Particulate (PM_{2.5})

The 2009 BAM readings produced an annual PM_{2.5} average of 5µg/m³. There were only two exceedances of the NWT 24-hour standard (30 µg/m³) for PM_{2.5}, which occurred in July. These exceedances are attributed to long distant transport of smoke from forest fires burning in Alaska and the Yukon at that time. Relative to previous years, impacts from forest fires were negligible in 2009.

Figure 11: 2009 Inuvik BAM PM_{2.5}

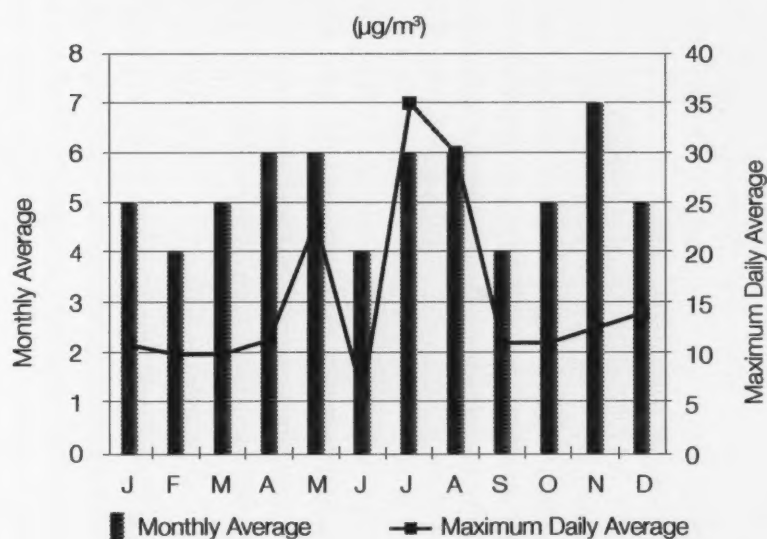


Figure 11 shows the monthly averages and maximum daily averages of the PM_{2.5} measured from the BAM at the Inuvik station in 2009. The maximum 24-hour PM_{2.5} value of 35µg/m³ occurred during the month of July and was attributed to forest fire smoke.

Coarse Particulate (PM₁₀)

The maximum daily average measured from the PM₁₀ BAM in Inuvik in 2009 was 175 µg/m³, recorded in May, which coincided with the highest hourly maximum (415 µg/m³). There were 10 exceedances of the adopted 24-hour standard (50 µg/m³), which generally occurred in the snow-free months. Similar to previous years, the spring-time levels were elevated and were representative of the typical 'spring-time dust event' associated with residual winter gravel.

The PM₁₀ exceedances were more numerous than previous years, which may be attributed to influences from local construction activities.

Figure 12: 2009 Inuvik BAM PM₁₀

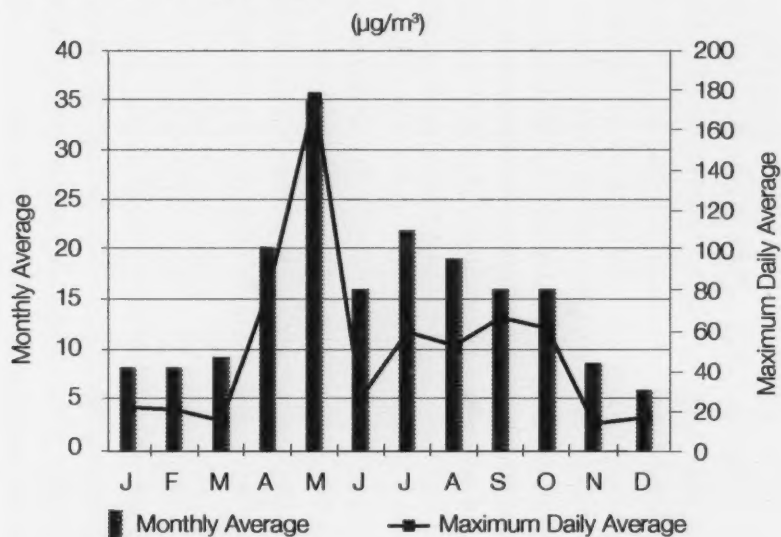


Figure 12 shows the monthly averages and the maximum daily average concentrations of PM₁₀ from the BAM in Inuvik. The spring spike is attributed to the residual winter gravel following the thaw.

Ground Level Ozone (O₃)

The maximum 1-hour average was 112 µg/m³, while the maximum 8-hour average was 106 µg/m³. Neither the 1-hour national standard (160 µg/m³) nor the 8-hour NWT standard (127 µg/m³) for ground level ozone was exceeded in 2009. The annual average was 40 µg/m³, which is typical of background levels.

The typical elevated readings in the spring-time were observed, which is consistent with historical data.

Figure 13: 2009 Inuvik Ozone

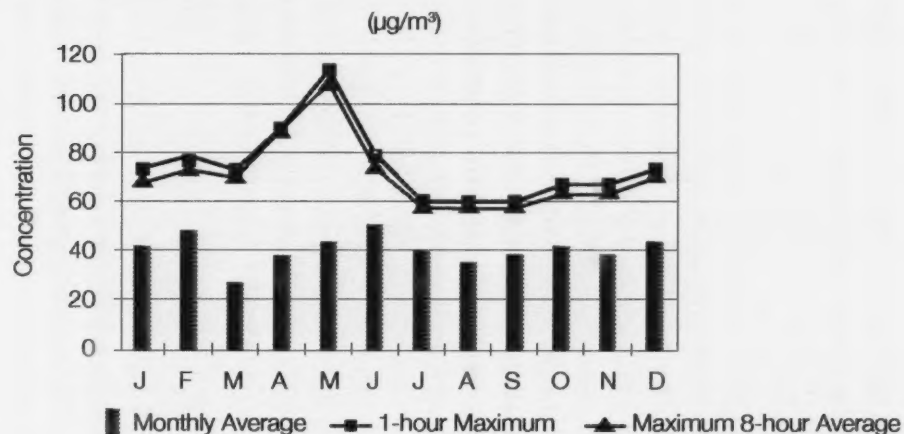


Figure 13 shows the maximum hourly and maximum 8-hour average per month as well as the monthly averages for ground level ozone recorded in 2009.

FORT LIARD AIR QUALITY

The focus of the monitoring station in Fort Liard is to gather baseline community air quality information and to track trends and cumulative effects of pollutant sources over time.

The station measures SO_2 , H_2S , NO_x , O_3 , $\text{PM}_{2.5}$ and PM_{10} , and has been in operation for select parameters since 2000. Note that the O_3 analyzer was installed in 2007.

Hydrogen Sulphide (H_2S)

The maximum hourly H_2S concentration in 2009 was $3\mu\text{g}/\text{m}^3$ and the vast majority of readings were less than $1\mu\text{g}/\text{m}^3$, essentially within the detection limits or 'noise' range of the analyzer. H_2S in Fort Liard is, therefore, considered largely non-detectable and within the limits of the Alberta guidelines (1-hour average of $14\mu\text{g}/\text{m}^3$ and a 24-hour average of $4\mu\text{g}/\text{m}^3$).

Sulphur Dioxide (SO_2)

As in previous years, there were no hourly or 24-hour exceedances of the NWT standards in 2009 (1-hour average of $450\mu\text{g}/\text{m}^3$, 24-hour average of $150\mu\text{g}/\text{m}^3$ and annual average of $30\mu\text{g}/\text{m}^3$), with a maximum 1-hour average value of only $8\mu\text{g}/\text{m}^3$. The monthly averages were very low, with values less than $3\mu\text{g}/\text{m}^3$. These readings are consistent with those measured over the last four years.

Fine Particulate (PM_{2.5})

The 2009 annual PM_{2.5} average concentration was 3 µg/m³, which is even lower than the 2008 annual average. The maximum daily average was 27 µg/m³. There were no exceedances of the NWT 24-hour standard for PM_{2.5} (30 µg/m³). These results indicate that Fort Liard was not significantly impacted by forest fire smoke in 2009.

Figure 14: 2009 Fort Liard BAM PM_{2.5}

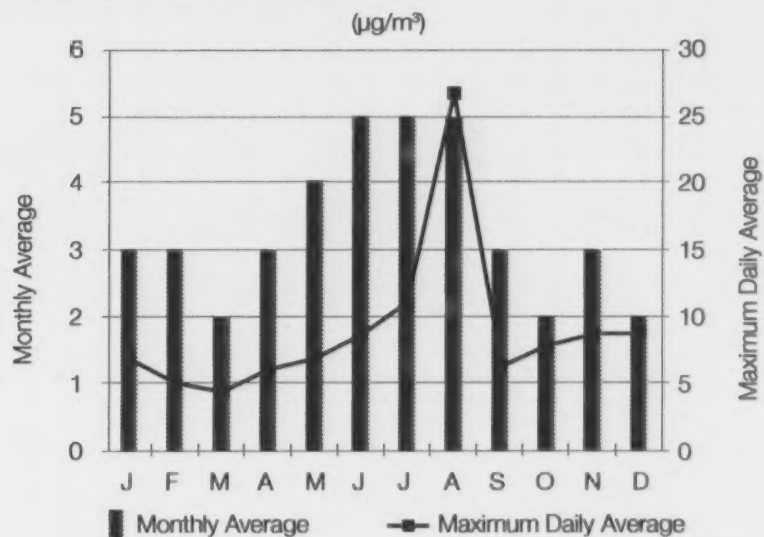


Figure 14 shows the monthly averages and maximum daily averages for PM_{2.5} measured from the BAM at the Fort Liard station in 2009.

Coarse Particulate (PM₁₀)

The highest daily maximum for PM₁₀ was 52 µg/m³ recorded in May and it was also the only exceedance of the adopted 24-hour standard (50 µg/m³). Elevated PM₁₀ readings were measured from May until September, which represent the snow-free months of the year and are attributed to the presence of gravel roads throughout Fort Liard. These results are expected and are consistent with previous years.

Figure 15: 2009 Fort Liard BAM PM₁₀

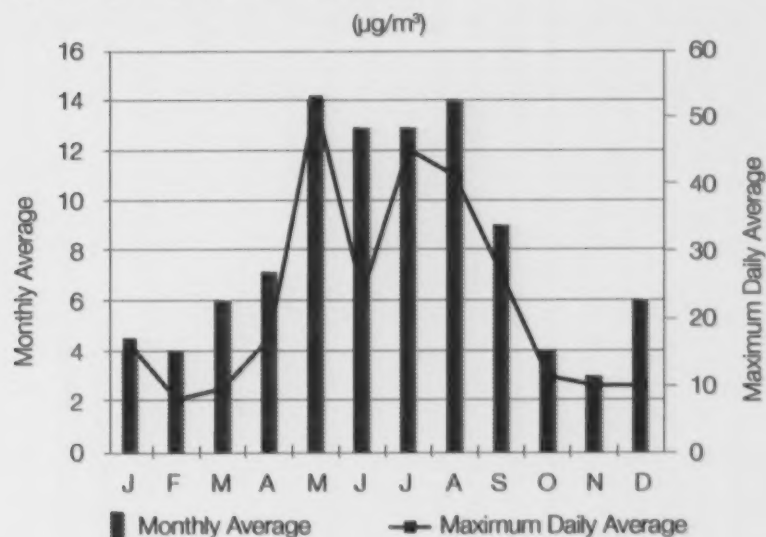


Figure 15 shows the monthly averages and the maximum daily average concentrations of PM₁₀ measured from the BAM in Fort Liard in 2009.

Nitrogen Oxides (NO_x)

The NO_x analyzer was taken off-line in March of 2009 following a major component failure. The data collected for those first few months of 2009 were invalidated once it was determined that the failure caused erroneous readings. The NO_x analyzer was not yet replaced by the end of 2009.

Ground Level Ozone (O₃)

2009 represents the second full year that ozone data was collected at the Fort Liard station.

The maximum 1-hour average was 112 $\mu\text{g}/\text{m}^3$, while the maximum 8-hour average was 108 $\mu\text{g}/\text{m}^3$. Neither the 1-hour national standard (160 $\mu\text{g}/\text{m}^3$) nor the 8-hour NWT standard (127 $\mu\text{g}/\text{m}^3$) for ground level ozone was exceeded in 2009. The typical elevated readings in the spring-time were observed, which is consistent with historical data.

Figure 16: 2009 Fort Liard Ozone

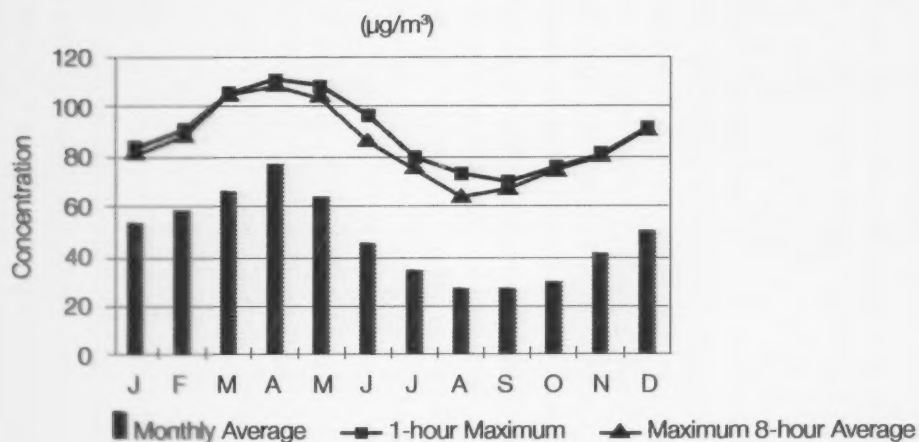


Figure 18 shows the maximum hourly and maximum 8-hour average per month as well as the monthly averages for ground level ozone recorded in Fort Liard 2009.

NORMAN WELLS AIR QUALITY

The focus of the monitoring station in Norman Wells is to gather baseline community air quality information and to track trends and cumulative effects of pollutant sources over time.

The station measures SO_2 , H_2S , NO_x , O_3 and $\text{PM}_{2.5}$, and has been in operation since 2003.

Hydrogen Sulphide (H_2S)

The maximum hourly H_2S concentration in 2009 was $5\mu\text{g}/\text{m}^3$ and the vast majority of readings were less than $1\mu\text{g}/\text{m}^3$, essentially within the detection limits or 'noise' range of the analyzer. The maximum 24-hour average was $2\mu\text{g}/\text{m}^3$. H_2S in Norman Wells is, therefore, considered largely non-detectable and within the limits of the Alberta guidelines (1-hour average of $14\mu\text{g}/\text{m}^3$ and a 24-hour average of $4\mu\text{g}/\text{m}^3$). The 2009 results are consistent with previous years.

Sulphur Dioxide (SO_2)

Overall SO_2 concentrations in Norman Wells were generally very low. The 1-hour maximum SO_2 reading was $8\mu\text{g}/\text{m}^3$, the maximum 24-hour average was $5\mu\text{g}/\text{m}^3$ and the annual average was less than $3\mu\text{g}/\text{m}^3$. No exceedances of the NWT standards occurred (1-hour average of $450\mu\text{g}/\text{m}^3$, 24-hour average of $150\mu\text{g}/\text{m}^3$ and annual average of $30\mu\text{g}/\text{m}^3$). This is consistent with previous years.

Nitrogen Oxides (NO_x)

The 2009 NO₂ results for Norman Wells show that the maximum 1-hour average was 73 µg/m³, the maximum 24-hour average was 10 µg/m³ and the overall annual average was 2 µg/m³, which were within the national standards (400, 200, 60 µg/m³, respectively). As with previous years, NO₂ levels were observed to increase in the winter months as a function of idling and other combustion sources during inversions (stagnant air masses).

Figure 17: 2009 Norman Wells Nitrogen Dioxide

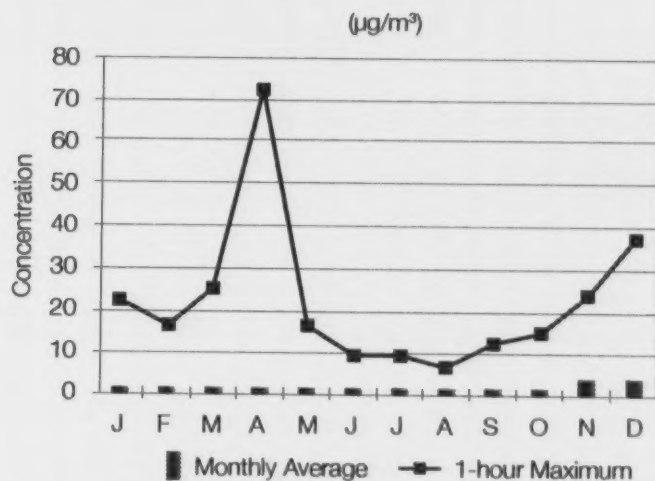


Figure 17 shows the 2009 monthly averages and maximum 1-hour concentrations of NO₂ in Norman Wells.

Fine Particulate (PM_{2.5})

The maximum daily average concentration of PM_{2.5} was 32 µg/m³ and the annual average was 5 µg/m³. This represents the single exceedance of the NWT standards measured in 2009 (24-hour average of 30 µg/m³).

The slight elevated readings measured in July and August are attributed to forest fire smoke from the Yukon and Alaska.

Figure 18: 2009 Norman Wells BAM PM_{2.5}

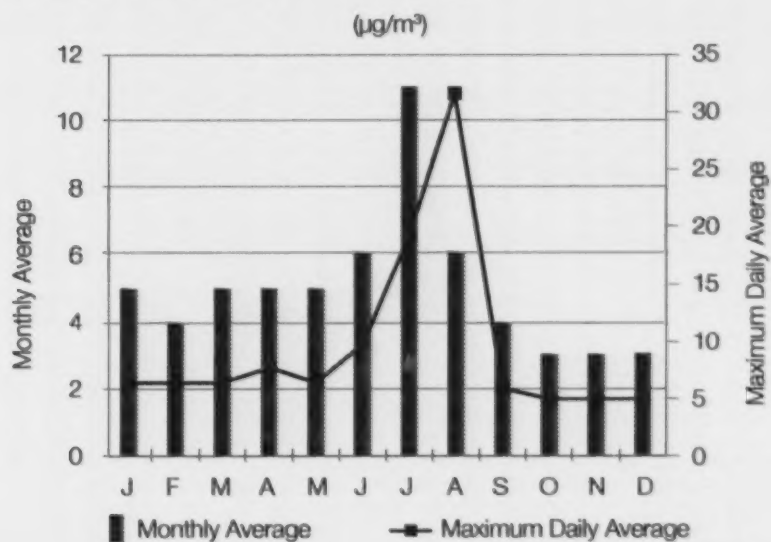


Figure 18 shows the monthly averages and maximum daily averages of PM_{2.5} measured from the BAM at the Norman Wells station in 2009.

Ground Level Ozone (O_3)

The maximum 1-hour average was $108\mu\text{g}/\text{m}^3$, while the maximum 8-hour average was $100\mu\text{g}/\text{m}^3$. Neither the 1-hour national standard ($160\mu\text{g}/\text{m}^3$) nor the 8-hour NWT standard ($127\mu\text{g}/\text{m}^3$) for ground level ozone was exceeded in 2009. The annual average was $44\mu\text{g}/\text{m}^3$, which is within the range of what is considered background levels. The typical elevated readings in the spring-time were observed, which is consistent with historical data.

Figure 19: 2009 Norman Wells Ozone

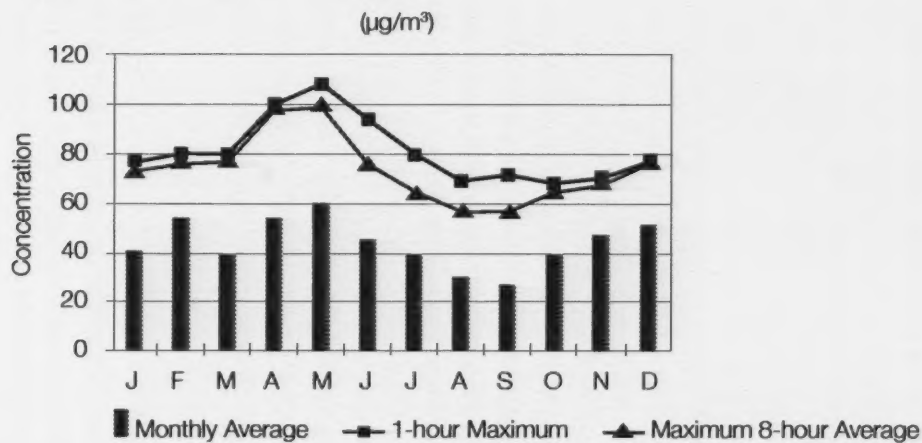


Figure 19 shows the maximum hourly and maximum 8-hour average per month as well as the monthly averages for ground level ozone recorded in Norman Wells 2009.

SNARE RAPIDS

Since 1989, ENR has operated a Canadian Air and Precipitation Monitoring (CAPMoN) station at the NWT Power Corporation's Snare Rapids hydro site. This site is located 150 kilometres northwest of Yellowknife. Rain and snow samples are collected on a daily basis and sent to Environment Canada's CAPMoN laboratory in Toronto for analysis of precipitation chemistry. Select results are presented below.

Figure 20: Snare Rapids Acid Deposition

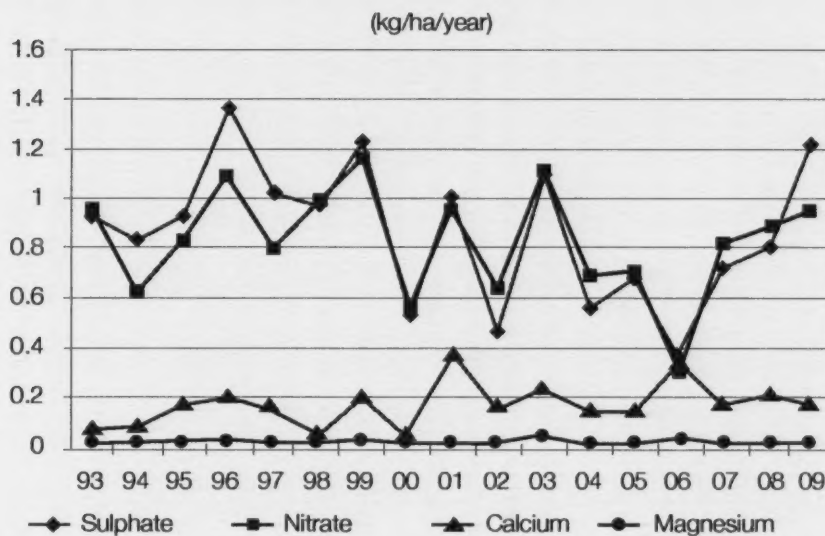


Figure 20 shows the deposition rates for sulphate, calcium, nitrate and magnesium from 1993 to 2009.

The sulphate level of deposition that is considered to be protective of sensitive ecosystems in the NWT is 7 kg/ha/yr. In areas of eastern Canada where acid rain is a more serious environmental problem, sulphate deposition has been measured by CAPMoN in excess of 20 kg/ha/yr. Nitrate deposition at Snare Rapids is also low relative to eastern Canada. Sulphate and nitrate deposition rates measured at Snare Rapids remain below levels that could cause an environmental effect in sensitive ecosystems.

DARING LAKE SEASONAL PARTICULATE

The mini-partisol particulate sampler required repair after the 2008 sampling season; unfortunately, the sampler is no longer manufactured or supported and, therefore, no particulate sampling was conducted during 2009 at Daring Lake. ENR anticipates that monitoring will resume in the future upon acquisition of new equipment.



APPENDIX A: MONITORING HISTORY

History of Air Quality Monitoring in the Northwest Territories	
1974	<ul style="list-style-type: none"> Government of the NWT starts monitoring air quality in Yellowknife with the installation of a high-volume air sampler at the Post Office site.
1989	<ul style="list-style-type: none"> Monitoring of acid precipitation at the Snare Rapids hydro-electric site begins.
1992	<ul style="list-style-type: none"> SO₂ analyzer installed at the City Hall site.
1997	<ul style="list-style-type: none"> SO₂ monitoring in N'dilo begins and continues until 2000.
1998	<ul style="list-style-type: none"> O₃ analyzer added in Yellowknife to the City Hall site.
2000	<ul style="list-style-type: none"> A SO₂ analyzer was installed in the ENR building in Fort Liard in March, followed by a H₂S analyzer in October.
2002	<ul style="list-style-type: none"> Daring Lake summer sampling of PM₁₀ at Daring Lake begins. City Hall SO₂ analyzer relocated to new air monitoring trailer located at Sir John Franklin High School.
2003	<ul style="list-style-type: none"> Daring Lake summer sampling of PM_{2.5} begins (the same sampler is used for PM₁₀ and PM_{2.5} monitoring). Air monitoring trailers are installed in Inuvik, Norman Wells and Fort Liard. CO and NO_x analyzers added to the Yellowknife station as well as a continuous fine particulate sampler (PM_{2.5}). Norman Wells station monitors SO₂ and H₂S. Inuvik station monitors SO₂, H₂S, NO_x and PM_{2.5}. Fort Liard station monitors SO₂ and H₂S. A PM_{2.5} sampler is installed late in the year. The O₃ analyzer that was operating at the City Hall location was relocated to the new Sir John Franklin Yellowknife station. ENR initiates the upgrade of the Data Acquisition System moving to a specialized air monitoring system, which will allow more efficient and quality controlled data collection. Continuous PM_{2.5} samplers are installed in Inuvik and Fort Liard. A second high-volume sampler is installed at the Sir John Franklin Yellowknife station.
2004	<ul style="list-style-type: none"> PM_{2.5} sampler is installed in Norman Wells. Data Acquisition System (DAS) is significantly upgraded. New components are installed inside the stations and a new data management, analysis and reporting system is brought on-line.

History of Air Quality Monitoring in the Northwest Territories (cont.)	
2005	<ul style="list-style-type: none"> • NO_x analyzer is installed in March at the Fort Liard station. • O₃ and NO_x analyzers are installed at the Norman Wells station in April. • O₃ analyzer purchased by Environment Canada (Yellowknife office) is installed at the Inuvik station in April. • Due to years of significant data loss caused by extreme cold, the partisol dichotomous fine particulate sampler at the Post Office station in Yellowknife is relocated indoors at the Sir John Franklin station. • The Yellowknife Post Office station is officially closed after the last TSP sample ran on December 6, 2005. • Development of an Air Quality web site begins. The web site will link with the data management, analysis and reporting system to provide public access to air quality data for each monitoring location. Access to archived data will also be available by querying the database using web-based tools.
2006	<ul style="list-style-type: none"> • Yellowknife – A BAM particulate matter (PM₁₀) monitor was installed and began collecting data in April. • Inuvik – A BAM particulate matter (PM₁₀) monitor was installed and began collecting data in October. • The Air Quality Monitoring Network web site was officially released.
2007	<ul style="list-style-type: none"> • Fort Liard – A BAM particulate matter (PM₁₀) monitor and an ozone (O₃) analyzer were installed and began collecting data in late August. • Completed the second phase of the Air Quality Monitoring Network web site, which included database related modifications as well as web design improvements.
2008	<ul style="list-style-type: none"> • No significant changes to the network.
2009	<ul style="list-style-type: none"> • Norman Wells – PM₁₀ BAM installed to complete particulate sampling throughout the network. • Yellowknife – Hi-vol sampler discontinued from all NAPS stations. • Daring Lake particulate monitoring temporarily discontinued due to malfunction.

APPENDIX B: AIR POLLUTANTS

The NWT Air Quality Monitoring Network tracks a number of different air pollutants. With the exception of arsenic and H_2S , these pollutants are known as Criteria Air Contaminants (CAC's). They represent the gases and compounds most often affecting community air quality and targeted by monitoring programs.

Arsenic is monitored in Yellowknife due to its association with metal ore roasting operations in the past and an ongoing concern during remediation work currently being undertaken at the former industrial sites.

H_2S is monitored at the air quality stations in Inuvik, Norman Wells and Fort Liard due to its association with oil and gas development activities.

Total Suspended Particulate (TSP)

Total suspended particulate (TSP) is a general term for dust. TSP includes a wide variety of solid and liquid particles found floating in the air, with a size range of approximately 50 micrometers (μm) in diameter and smaller (a human hair is approximately $100\mu m$ in diameter). While TSP can have environmental and aesthetic impacts, it is the smaller particles contained within TSP that are of concern from a human health perspective (see Particulate Matter ($PM_{2.5}$) and (PM_{10}) later in section). Road dust, forest fires, mining activities and combustion products from vehicles, heating and electricity generation contribute to TSP levels.

The NWT Ambient Air Quality Standard for TSP is $120\mu g/m^3$ over a 24-hour period. The standard for the annual average is $60\mu g/m^3$ (geometric mean).

Arsenic

Arsenic is present in the environment in a variety of forms. The most common form in air is the inorganic compound arsenic trioxide. Natural sources of airborne arsenic include volcanoes and windblown dust from arsenic rich soils, while industrial activities such as smelting and burning of coal account for most of the man-made sources. The vast majority of airborne arsenic is associated with dust and, therefore, analysis of TSP samples provides a good indication of arsenic concentrations.

There are no NWT standards for arsenic compounds. The World Health Organization (WHO) Air Quality guidelines (WHO, 2000) state that inhaling inorganic arsenic compounds can contribute to human development of cancer and there is no safe limit. It is, therefore, important to minimize exposure as much as possible, since the cancer risk increases with exposure to higher concentrations.

As the threshold for arsenic compounds has not been set, it is difficult to determine an acceptable level. Ontario continues to use a 24-hour guideline of $0.3\mu\text{g}/\text{m}^3$ for total arsenic based on general toxicity, but the WHO suggest that a lifetime risk estimate approach should be used for assessment purposes. The WHO has calculated the following lifetime risk estimates of contracting cancer due to exposure to varying concentrations of arsenic in air:

- $0.066\mu\text{g}/\text{m}^3$ results in a theoretical risk of one person in 10,000.
- $0.0066\mu\text{g}/\text{m}^3$ results in a theoretical risk of one person in 100,000.
- $0.00066\mu\text{g}/\text{m}^3$ results in a theoretical risk of one person in 1,000,000.

In simple terms, the above estimates indicate, for example, that in a population of 10,000 people, a lifetime exposure to an arsenic concentration of $0.066\mu\text{g}/\text{m}^3$ could theoretically result in one person contracting cancer. The Ontario guideline provides a useful comparison for assessment of short-term (24-hour) arsenic measurements, but the WHO approach is probably more applicable given the longer-term health risks associated with arsenic exposure.

Particulate Matter ($\text{PM}_{2.5}$) and (PM_{10})

A sub-portion of TSP, these very small particulates are named for the diameter size of the particles contained within each group – PM_{10} contains particles with a diameter of 10 microns (1 millionth of a metre) or less, while $\text{PM}_{2.5}$ (a sub-portion of PM_{10}) contains particles with a diameter of 2.5 microns or less. The significance of these microscopic particles is that they can be inhaled and are associated with health effects, including aggravation of existing pulmonary and cardiovascular disease. Generally, the smaller the particle, the greater the penetration into the lung and the greater the associated health risk.

Sources of particulates that can be inhaled include road dust and wind blown soil, which make up the majority of the PM_{10} particles. Particles in the $\text{PM}_{2.5}$ size range primarily result from combustion of fossil fuels for industrial activities, commercial and residential heating as well as vehicle emissions, forest fire smoke and chemical reactions between other gases emitted to the air.

The national Canada-wide Standards (CWS) process has set an acceptable limit for $\text{PM}_{2.5}$, but has not yet established a limit for PM_{10} . The CWS 24-hour average acceptable limit for $\text{PM}_{2.5}$ is $30\mu\text{g}/\text{m}^3$ and this concentration has been adopted under the NWT *Environmental Protection Act* as the NWT Ambient Air Quality Standard for $\text{PM}_{2.5}$. Several Canadian jurisdictions (e.g. BC, Ontario, Newfoundland and Labrador) have adopted a PM_{10} concentration of $50\mu\text{g}/\text{m}^3$ (24-hour average) as an acceptable limit.

Sulphur Dioxide (SO₂)

SO₂ is a colourless gas, with a pungent odour at elevated concentrations, which can have negative effects on human and environmental health. Certain types of vegetation (especially lichens) are very sensitive to SO₂ impacts. SO₂ also plays a role in acid deposition and formation of secondary fine particulate through chemical reactions with other pollutants in the air.

There are some natural sources of SO₂ in ambient air (forest fires, volcanoes), but human activity is the major source. Emissions of SO₂ primarily result from the burning of fossil fuels containing sulphur. Sources include natural gas processing plants, gas plant flares and oil refineries, metal ore smelting, power generating plants and commercial or residential heating.

The NWT Ambient Air Quality Standards for SO₂ are 450 µg/m³ (1-hour average), 150 µg/m³ (24-hour average) and 30 µg/m³ (annual average).

Hydrogen Sulphide (H₂S)

Hydrogen sulphide (H₂S) is a colourless gas with a characteristic rotten egg odour. At high concentrations (parts per million range), it can be toxic, but typical ambient (outdoor) concentrations, even in areas impacted by industrial sources, tend to fall in the parts per billion (ppb) range. However, due to its low odour threshold, the presence of H₂S can be offensive and it has been associated with eye irritation and triggering feelings of nausea in sensitive individuals.

Industrial sources include oil and gas extraction, petroleum refining, sewage treatment facilities and pulp and paper mills. Natural sources include sulphur hot springs, swamps and sloughs, which release H₂S as a by-product of organic decomposition.

There are no NWT standards for H₂S. The Alberta Ambient Air Quality Objectives provide an hourly limit of 14µg/m³ (or 10ppb) and a 24-hour limit of 4µg/m³ (or 3ppb), based on avoidance of odour.

Nitrogen Oxides (NO_x)

Nitrogen oxides (NO_x) consist of a mixture of nitrogen-based gases, primarily nitric oxide (NO) and nitrogen dioxide (NO₂). Emissions of both NO and NO₂ results from the high temperature combustion of fossil fuels. The predominant emission is NO, which then rapidly converts to NO₂ through chemical reaction in the atmosphere. NO is a colourless and odourless gas, whereas NO₂ is a reddish-brown colour with a pungent, irritating odour.

NO_2 is considered the more toxic and irritating of the two gases and, at elevated concentrations, is associated with both acute and chronic respiratory effects. Both gases play a role in the atmospheric reactions resulting in acid deposition and secondary pollutant formation (i.e. O_3 and fine particulate).

Because of the greater health effects of NO_2 , development of air quality standards has focused on this gas, rather than NO or total NO_x . There are no NWT standards for NO_2 , but the national standards provide values of $400\mu\text{g}/\text{m}^3$ (1-hour average), $200\mu\text{g}/\text{m}^3$ (24-hour average) and $60\mu\text{g}/\text{m}^3$ (annual average).

Ground Level Ozone (O_3)

Ground level ozone (O_3) should not be confused with stratospheric O_3 , which occurs at much higher elevations and forms a shield that protects life on the planet from the sun's harmful ultraviolet radiation. The gas is the same, but at ground level O_3 is regarded as undesirable due to its association with a variety of human health concerns, environmental impacts and property damage. O_3 is a highly reactive gas and is defined as a secondary pollutant. It is not emitted in large quantities from any source, but is formed through a series of complex chemical reactions involving other pollutants called precursors (e.g. NO_x and volatile organic compounds or VOCs) in the presence of sunlight.

The national standards provide a maximum acceptable level of $160\mu\text{g}/\text{m}^3$ for O_3 based on a 1-hour average. The Canada-wide Standards (CWS) process has also set an acceptable limit of 65ppb or $127\mu\text{g}/\text{m}^3$ based on an 8-hour average. The CWS 8-hour limit has been adopted under the NWT *Environmental Protection Act* as the NWT Ambient Air Quality Standard for O_3 .

Carbon Monoxide (CO)

Carbon monoxide (CO) is a colourless, odourless and tasteless gas produced by the incomplete combustion of fuels containing carbon. The primary source is vehicle exhaust, especially in cities with heavy traffic congestion. Other sources include industrial processes and fuel combustion for building heating. One natural source is wildfires.

CO affects humans and animals by interfering with the ability of the blood to transport oxygen around the body.

There are no NWT standards for CO, but the most stringent national standards provide a value of $15\text{mg}/\text{m}^3$ (1-hour average) and $6\text{mg}/\text{m}^3$ (8-hour average). CO values are reported in mg/m^3 as opposed to other gaseous pollutants, which are reported in $\mu\text{g}/\text{m}^3$.

Acid Deposition

Acidity in precipitation is measured in pH units on a scale of 0 to 14. A value of seven indicates neutral, values less than seven indicate acidic conditions and values greater than seven indicate alkaline conditions. Even clean precipitation is slightly acidic – around pH5.6 – due to the presence of naturally occurring concentrations of carbon dioxide and minor amounts of sulphate and nitrate ions. The introduction of sulphur dioxide and nitrogen oxide emissions from combustion of fossil fuels for industrial, commercial and individual activities can result in an increase in acidic compounds in the atmosphere – often in areas far removed from the original emission sources. The removal of these sulphur and nitrogen compounds through atmospheric washout is reflected in the increased acidity (lower pH values) of precipitation. Calcium and magnesium ions – mostly from natural sources – act to neutralize acidity in precipitation.

Generally, precipitation with a pH value of 5.0 or less is termed 'acidic'. However, assessment of acid precipitation is usually based on deposition to an area over a specified time period (e.g. kilograms per hectare per year, kg/ha/yr) rather than review of specific precipitation event parameters. Also, the degree of impact to a particular environment is influenced by its 'buffering' capacity or ability to tolerate the acidic inputs. Therefore, determination of acceptable limits usually requires a range of values to reflect the differing tolerances of various areas.

